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5254

PROPERTIES OF THERMIT WELDED JOINTS IN REINFORCING BARS

58-10

AND

July 25, 1958

Materials and Research Department
Structural Materials Section
Work Supervised by J. L. Beaton
Report Prepared by P. G. Jonas

State of California
Department of Public Works
Division of Highways
Materials and Research Department

July 1958

Mr. W. G. Schulz, Chief Engineer
Division of Design and Construction
Department of Water Resources
1730 24th Street
Sacramento, California

Attention: Mr. T. Neuman, Assistant Division Engineer

Dear Sir:

Attached you will find report of test on Thermit welding of reinforcing bar of intermediate grade, which is proposed for the bridge at North Fork crossing of the Feather River, Specification No. 57-13.

The quality of weld required under Specification No. 57-13 for Thermit type welding is 85% of the tensile strength of the intermediate grade reinforcing bar. No other requirement was defined. Two bars, Nos. 1 and 10, of the sixteen tested for tensile strength failed to meet specified quality.

Two bars were selected for the beam test for ductility, bars No. 2 horizontal and No. 3 vertical. These bars, along with the rest of the tension tests, exhibit very little ductility as can be seen from the test report.

All bar assemblies vertical welded of the No. 18 size to No. 11 broke in the No. 11 bars.

Attached to the test report is a summary with pictures explaining the Thermit welding.

Pending your decision on whether or not to use this method of welding the reinforcing bars, we will make up a manual of inspection with radiographic pictures as a guide for your inspector, at your request.

Conclusion:

1. Thermit welding of reinforcing bars can be used to obtain 85% of the minimum specified ultimate tensile strength if properly controlled.

2. Thermit welding exhibits very little ductility.

3. Thermit welding is very active so the burning of concrete forms and personnel will be a hazard.

4. There will be some weld failures during welding in which the molten metal will flow out of the mold, so precautions should be taken for personal safety when welding overhead.

5. Defective Thermit welds can be repaired by the manual arc process using a low Hydrogen electrode of the E 7016 series.

6. To insure a more uniform weldment and the drying out of moisture, it is recommended that the reinforcing bars should be preheated to a temperature of 600° F at the butt ends at least 8" back on each side of the 3/8" Thermit spacing.

7. Manual welding can be performed using a low Hydrogen electrode of E 7016 series. This method will normally develop 85 to 90% joint efficiency of the reinforcing bars and will result in a ductility very nearly equivalent to the base material.

F. N. Hveem
Materials and Research Engineer

By John L Beaton
J. L. Beaton
Supervising Highway Engineer

PGJ:mw
Attach.
cc: TNeuman

Test No. 8 - 515
Contract No. 57-13
North Fork Crossing
Date: 7-18-58

Report of Tests on

Thermit Welding of Reinforcing Bars

Sample of Thermit welding on reinforcing steel obtained from the Bethlehem Steel, Pacific State Steel, and Columbia-Geneva Steel Companies and furnished by Joseph T. Ryerson & Sons.

Test Results

Pacific States Heat 13193 - C 43, Mn 50, P 010, S 045

Mill Test - Yield 45,330 - Ultimate 84,710 - Elongation 17%

Test	Bar Size	Weld Pos.	Mold Matl.	Yield	Ultimate	8" %Elong.	% Min. Spec. Ult.
2	18 to 18	Hor.	Silica	(Beam Test) 30" span	117,000 Fibre	0.17"	2-1/4"defl.
9	18 to 18	Hor.	Silica	43,800	72,200	5%	103%
3	18 to 18	Vert.	Zircon	(Beam Test) 30" span	93,000 Fibre	0.18"	2-3/8"defl.
14	18 to 18	Vert.	Zircon	43,750	70,500	5%	101%
15	18 to 18	Vert.	Zircon	43,800	75,250	5.5%	107%
16	18 to 18	Vert.	Zircon	43,800	70,000	5%	100%
17	18 to 18	25°Tilt	Silica	44,000	75,000	6%	106%
18	18 to 18	25°Tilt	Silica	44,000	70,000	6%	100%

Combined Reduced Section - #11 Columbia to #18 Pacific States

4	11 to 18	Vert.	Zircon	39,000	74,000	-	106%

Beam Test - 30" span loaded at center point -

$$\text{Beam Elong.} = \frac{2\ \text{Defl.}}{\text{Span}} \times \text{Radius of Bar}$$

Remarks: Special Thermit Compound S.A.E. 1040

Test No. 8 - 515

#11 and #18 deformed reinforcing bar intermediate grade minimum specified tensile - 70,000 psi

Bethlehem Heat #1 W074 - #18 bar - C 41, Mn 51, P 019, S 037
Columbia-Geneva Heat #79308 - #11 bar - C 39, Mn 47, P 028, S 064

Mill Test - Yield 40,000 - Ultimate 86,500 - Elongation 25%

Test	Bar Size	Weld Pos.	Mold Matl.	Yield	Ultimate	8" %Elong.	% Min. Spec. Ult.
18	18	Unwelded		47,500	83,000	18%	119%

Thermit Welded Flame Cut Ends

Test	Bar Size	Weld Pos.	Mold Matl.	Yield	Ultimate	8" %Elong.	% Min. Spec. Ult.
5	18 to 18	Hor.	Silica	45,000	66,700	5%	95%
6	18 to 18	Hor.	Silica	45,000	60,300	3%	86%
10	18 to 18	Hor.	Silica	45,300	52,500	1%	75%
1	18 to 18	Vert.	Zircon	45,500	53,600	4%	77%

Reduced Section (Combined) - #11 Columbia to #18 Bethlehem

Test	Bar Size	Weld Pos.	Mold Matl.	Yield	Ultimate	8" %Elong.	% Min. Spec. Ult.
7	11 to 18	Vert.	Zircon	39,000	73,600	-	105%
8	11 to 18	Vert.	Zircon	39,600	73,900	-	106%
13	11 to 18	Vert.	Zircon	39,600	74,000	-	106%

Remarks: Special Thermit compound S.A.E. 1040

Pacific States bar previously welded and broken and rewelded on opposite ends which were saw cut; 600°F preheat was used on the weld.

Test	Bar Size	Weld Pos.	Mold Matl.	Yield	Ultimate	8" %Elong.	% Min. Spec. Ult.
25	18 to 18	Hor.	Silica	43,750	62,500	1%	93.9%

Remarks: Broke out of weld. Special Thermit Compound S.A.E. 1040.

Thermit welding of #18 reinforcing bars for procedure test for Contract Specification No. 57-13, Bridge at North Fork Crossing, Feather River.

All welding was done by J. W. Houser, West Coast Representative of the Thermit Metallurgical Corp., 282 J Street, Livermore, California.

The Thermit welded specimens were welded at Joseph T. Ryerson & Sons, 65 Hollis Street, Emeryville, California, the subcontractor. With the exception of one #25 test weld, it was welded at location of Mr. J. W. Houser's, Livermore, California.

The source of reinforcing bars was that of Bethlehem Steel Company and Pacific States Steel Company, with physical and chemical test reports dated 6-16-58 for Pacific States Steel Corporation and dated 4-10-58 for Bethlehem Steel Company.

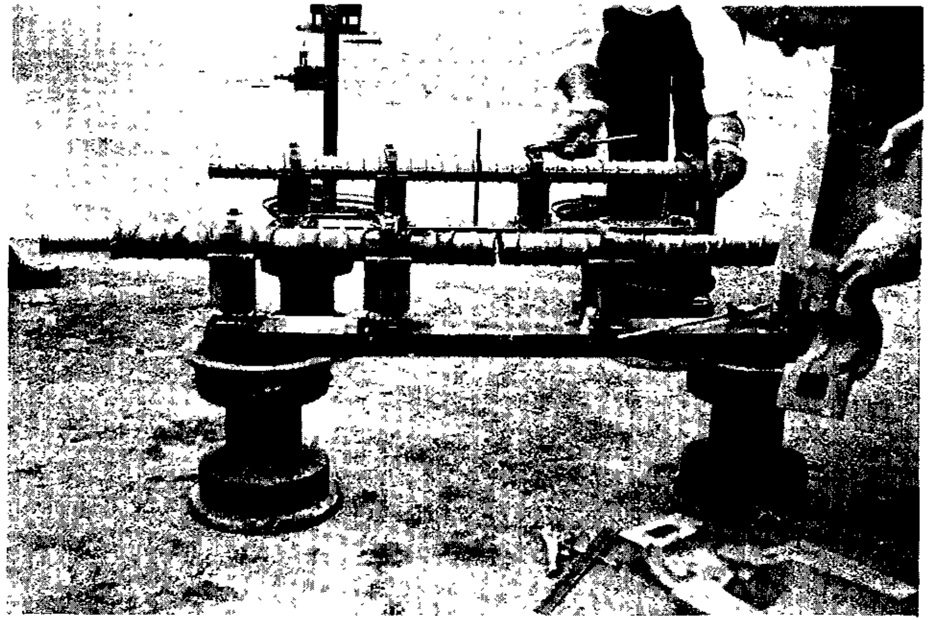
The Thermit welds of the number 18 reinforcing bars were aligned vertically and horizontally by means of jigs furnished by the welding contractor. The jigs were 4" channels with Vee blocks attached with hold-down clamps. These jigs are seen in the following pictures. The reinforcing bars were cut to approximately 30" in length and installed in the jigs aligned by the use of shims between the reinforcing bars and the Vee blocks. Alignment checked by the use of a straight edge with the gap of the butt ends of the bars set at 3/8" by use of a centering tool. The hold-down clamps were then tightened.

With the bars aligned and clamped in the jigs, the Thermit crucible molds were then installed; molds were aligned over the butt joint by the use of a steel centering tool; the two piece mold was held together with small clamps. The molds were aligned concentrically around the bars by use of small wooden wedges placed between the frame of the jig and the bottom side of mold.

With molds in place a special foundry sand is packed by hand around the reinforcing bars and into the recesses of the mold. This is called luting. This prevents molten metal from escaping between the mold and the bar.

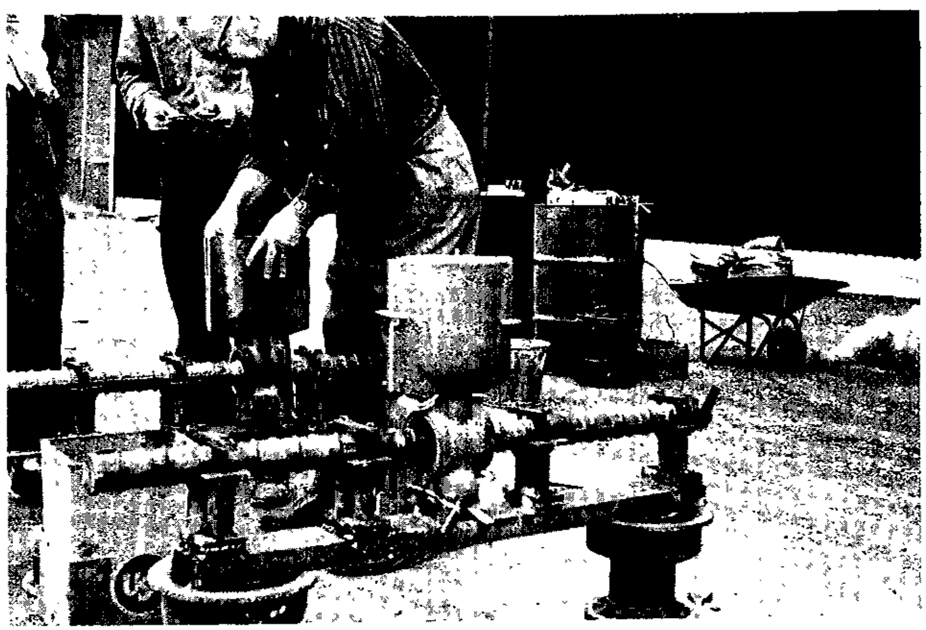
When mold has been luted, two small metal discs are inserted in the mold where a small space properly made to receive the discs. These discs are the tapping plug and it allows just enough time for the Thermit reaction to take place before tapping. A measured amount of Thermit compound is placed in the crucible mold with a small amount of starting Thermit powder added to the top of the Thermit compound and ignited with a lighter.

The tapping time is approximately 25 seconds from the start of ignition to flow of the molten metal through the mold.



Picture No. 1

The aligning and spacing of the reinforcing bars. The spacing of the reinforcing bars is very important to allow the molten metal to wash through the space for fusion.

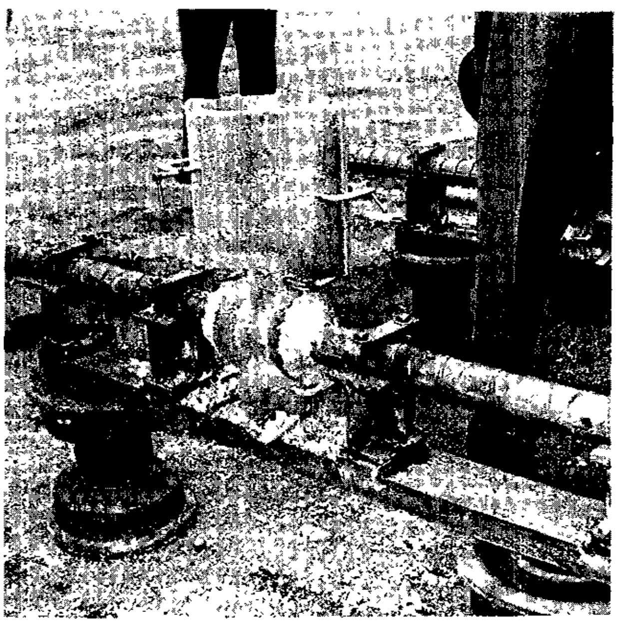


Picture No. 2

The thermit crucible is then clamped on the aligned and properly spaced reinforcing bars.

Picture No. 3

The thermit crucible is then packed with a luting sand in the luting area of the crucible mold. The luting or packing of the sand around the reinforcing bar is very important. If the sand is too dry, coarse, or not properly placed, the weld metal will burst out of the mold causing a defective weld.

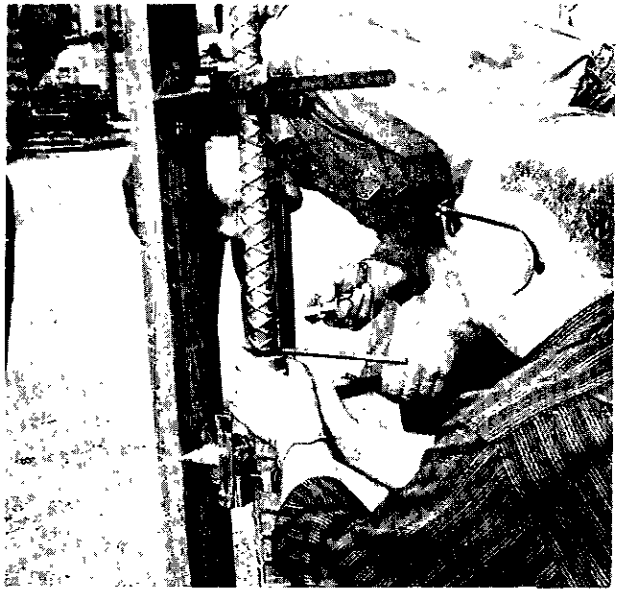


Picture No. 4

Here can be seen a thermit crucible packed with luting sand and ready for igniting.

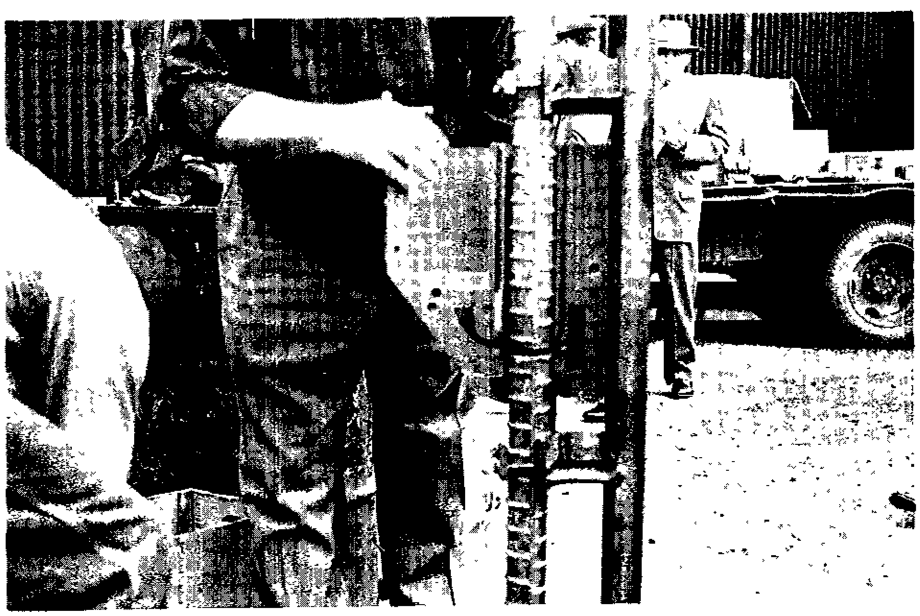
Picture No. 5

Thermit ignited and reaction taking place. Caution must be exercised when in the vicinity of flying molten metal.



Picture No. 1

The reinforcing bars are oxyacetylene cut square. It is very important not to have a rough cut or lack of fusion will result. The reinforcing bars are then put into a jig and properly spaced.



Picture No. 2

The crucible mold is then placed on the reinforcing bars with the tapping gate lined up with the bar spacing.

Picture No. 3

The mold and reinforcing bar is then packed with a luting sand. This is very important. If not properly packed, the weld metal will run out between the mold and reinforcing bar causing a defective weld.

Picture No. 4

The thermit is then placed into the crucible and ignited. Here can be seen a typical thermit weld reaction with molten metal splashing on the ground.

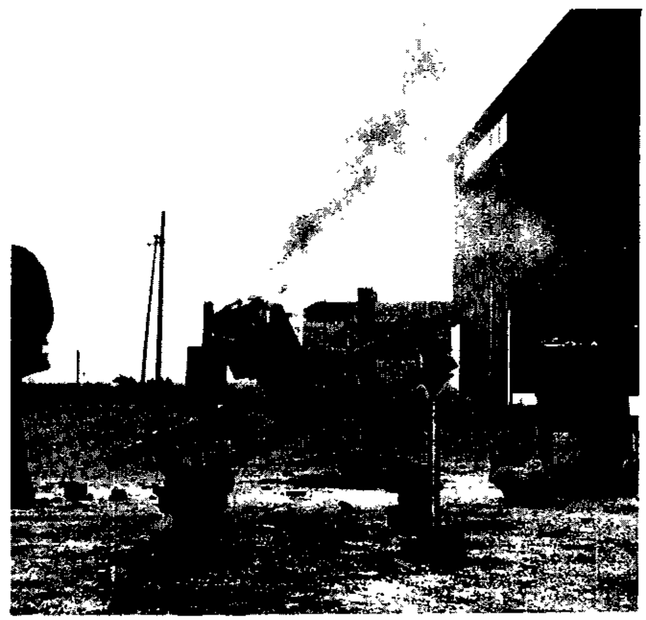
25° Tilt

Two test bars, No. 17 and No. 18, were welded on a 25° tilt. This is the maximum tilt that can be obtained with a horizontal thermit crucible mold.

The placing of the molds and spacing of the bars is the same as for horizontal thermit welding.

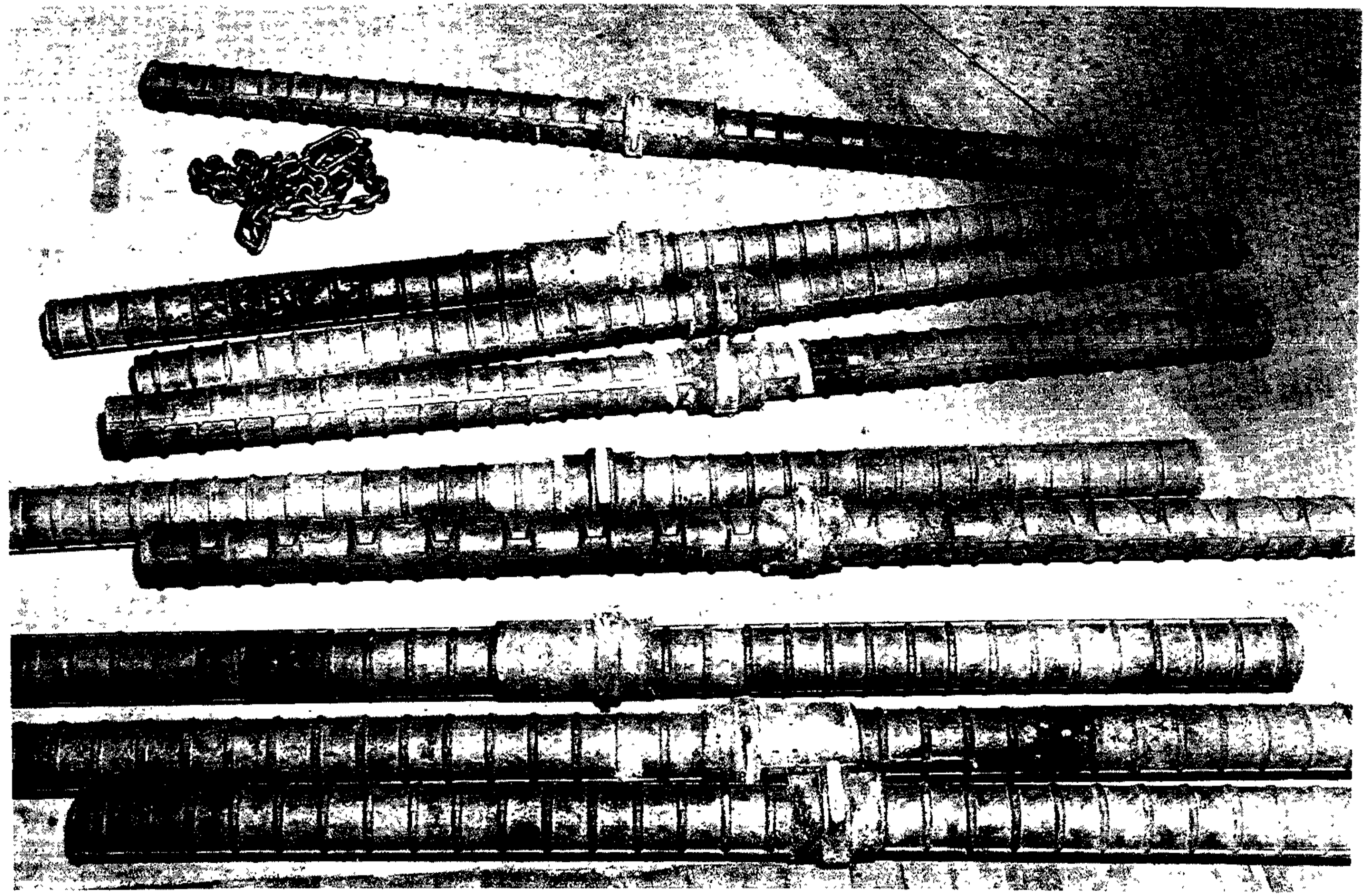
Picture No. 1

Reinforcing bar tilted on 25° angle, with crucible mold and sand luting in place ready for igniting.

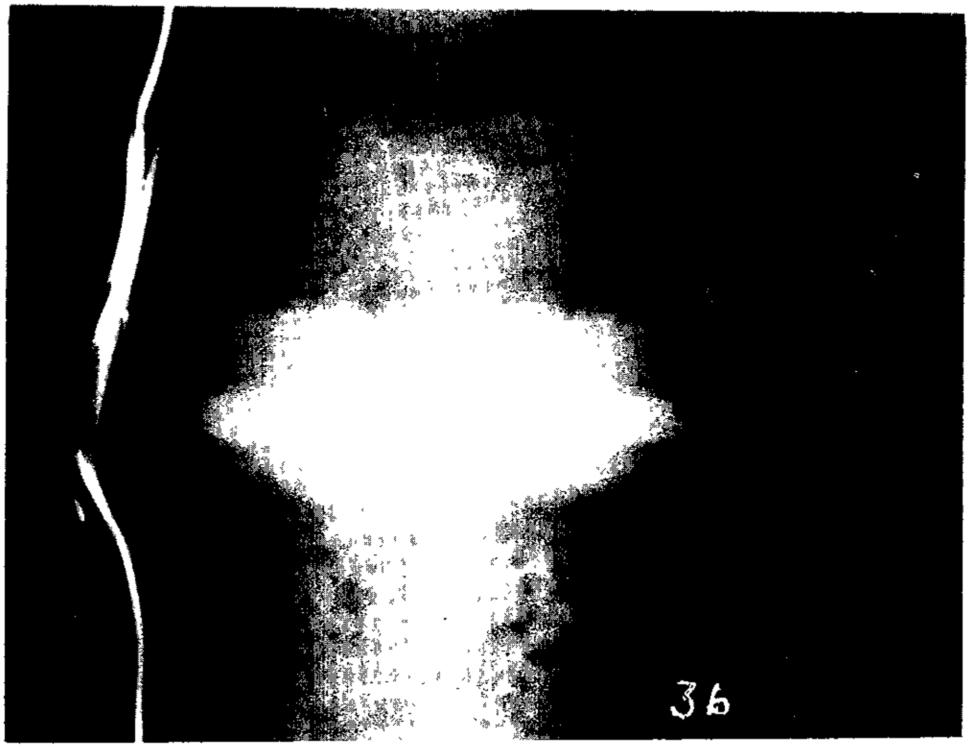


Picture No. 2

Thermit ignited and reaction taken place. All molds were allowed to cool down before stripping.

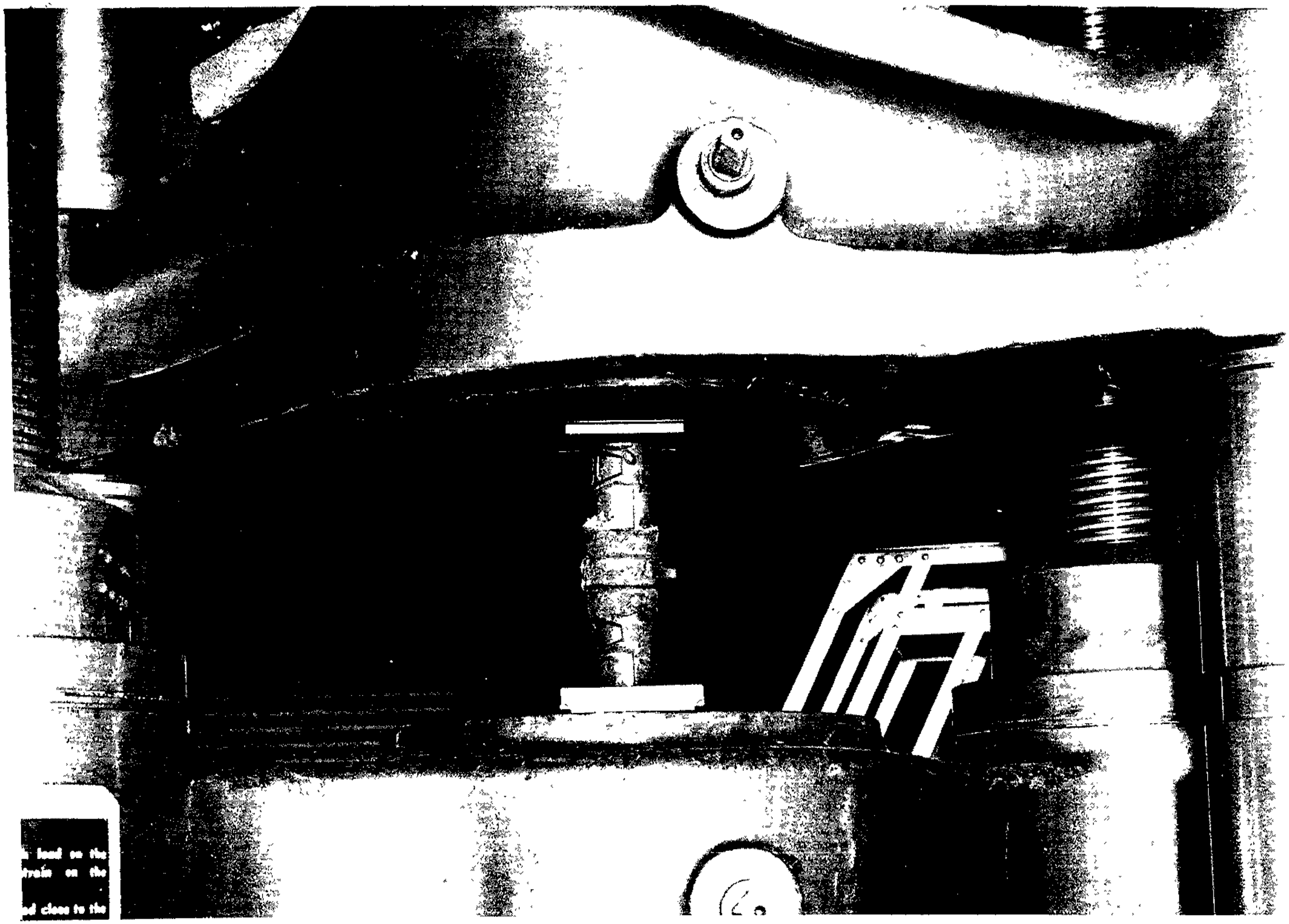


The typical vertical and horizontal thermit welds with the tapping gates and risers knocked off, ready for testing.



Typical radiograph of #3 beam test. There are a few gas voids in the center of the thermit weld. However this weld would be considered acceptable.

All test welds were radiographed before testing. These radiographs may be used for radiographic standards during construction.



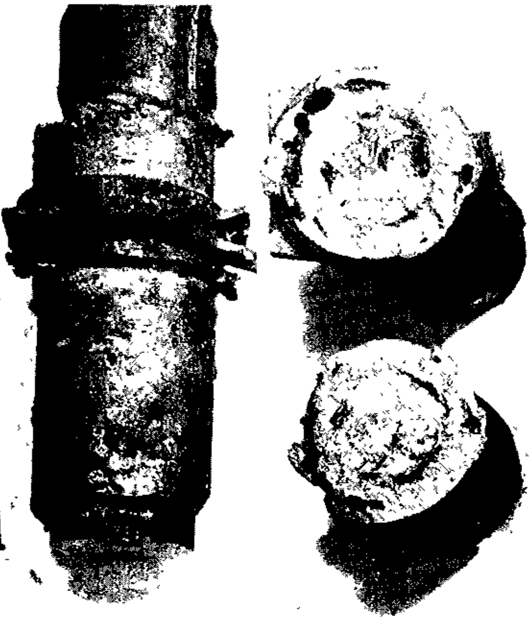
Typical tension test of thermit welded reinforcing bars.

Horizontal and vertical Thermit welded number 18 reinforcing bars.

Here can be seen typical breaks of the Thermit welds of the tension tests. The welds exhibit low ductility with large amount of voids or gas inclusions in the Thermit weld metal.

Thermit weld break locations.

Test Bars	Break Location
#1	Weld metal.
#2 Beam Test	Junction of weld metal and parent metal where the extreme notch is located from weld and weld-flashing.
#3 Beam Test	Junction of weld metal and parent metal where the extreme notch is located from weld and weld-flashing.
#4	Junction of weld metal and parent metal where the extreme notch is located from weld and weld-flashing.
#6	Weld metal.
#9	Junction of weld metal and parent metal where the extreme notch is located from weld and weld-flashing.
#10	Weld metal.
#14	Junction of weld metal and parent metal where the extreme notch is located from weld and weld-flashing.
#15	Junction of weld metal and parent metal where the extreme notch is located from weld and weld-flashing.
#16	Weld metal and parent metal.
#17	Junction of weld metal and parent metal where the extreme notch is located from weld and weld-flashing.
#18	Junction of weld metal and parent metal where the extreme notch is located from weld and weld-flashing.



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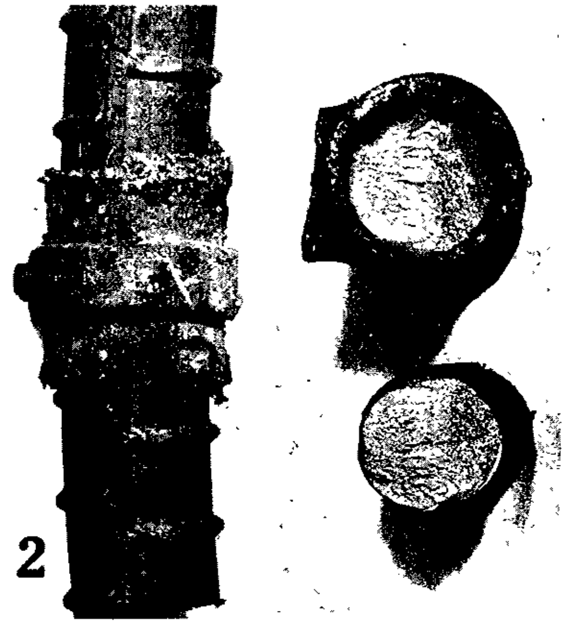

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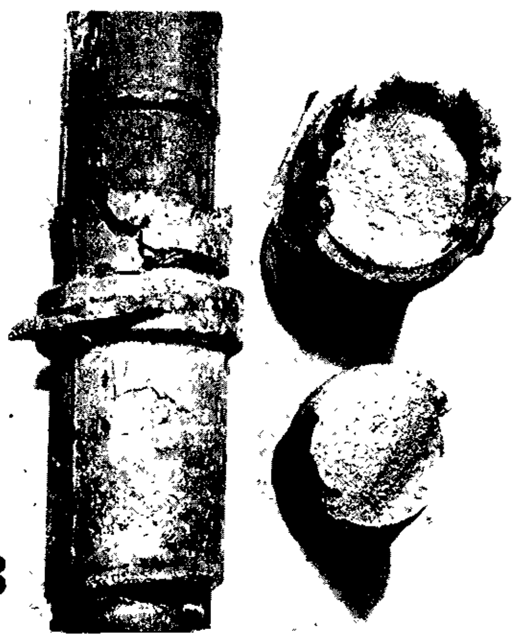

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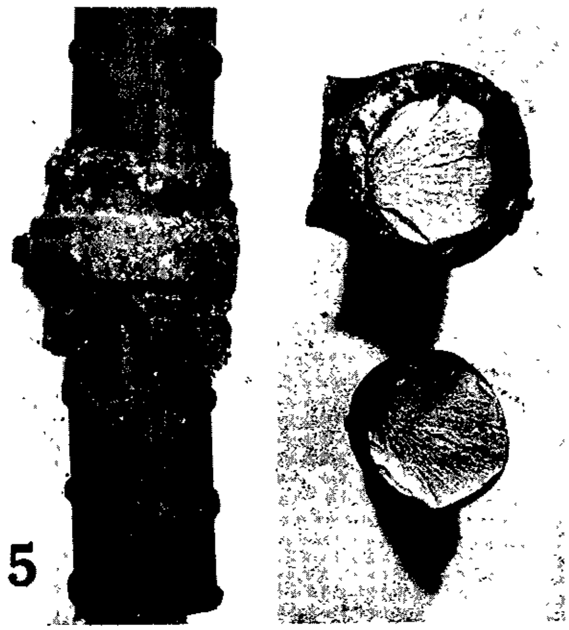

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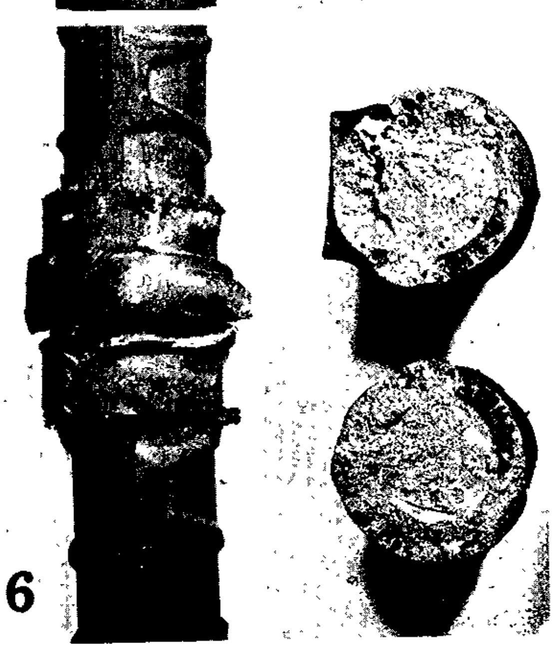

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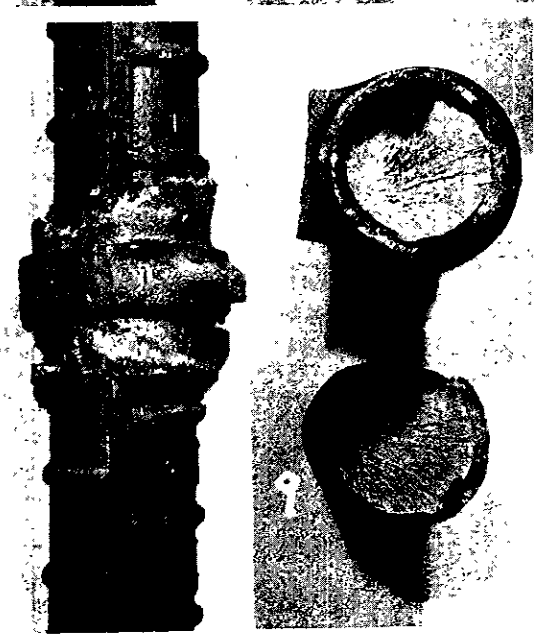

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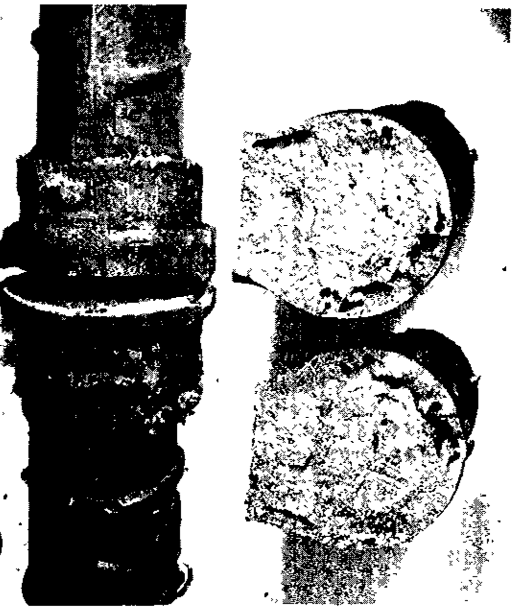

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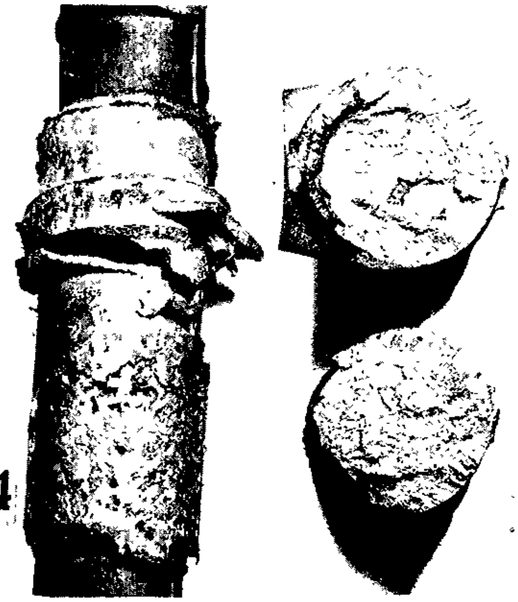

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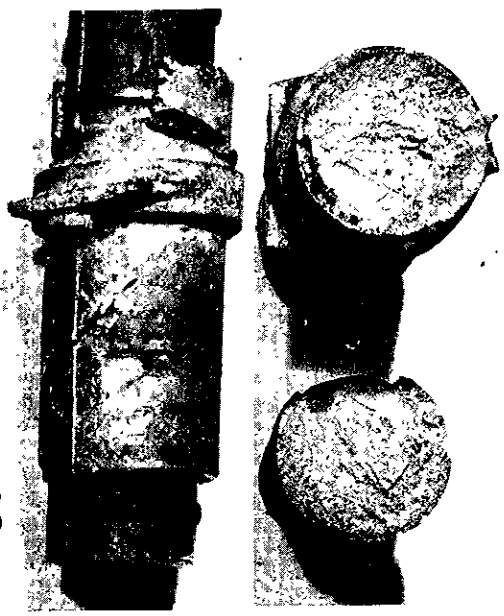

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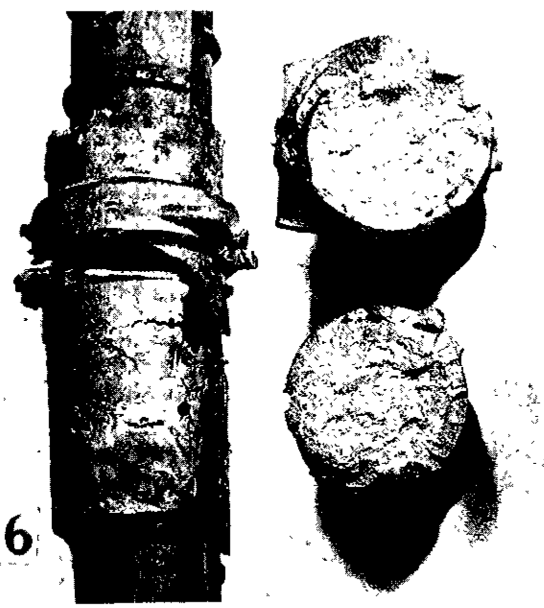

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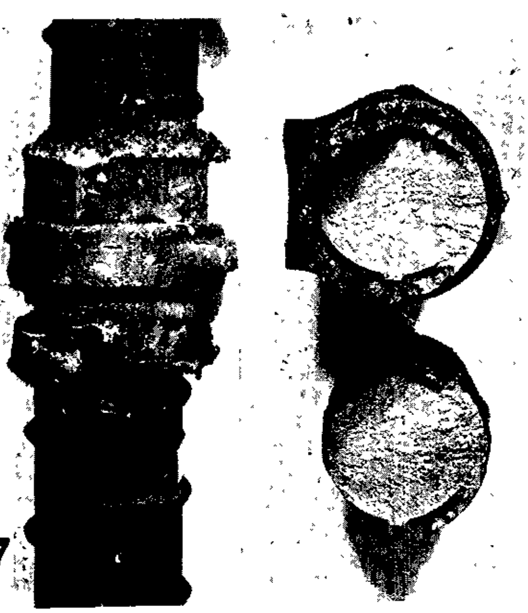

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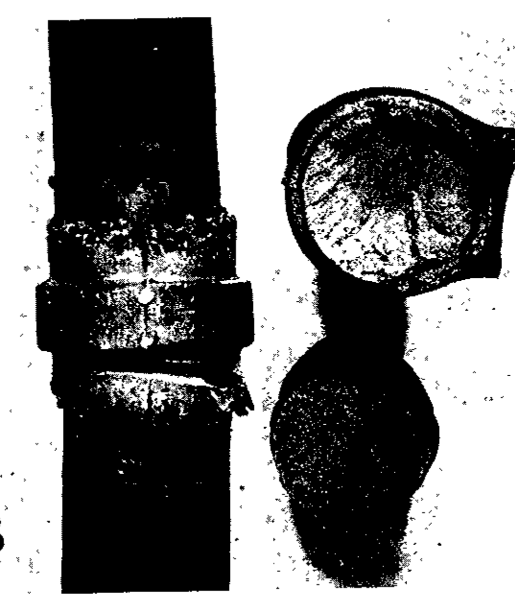

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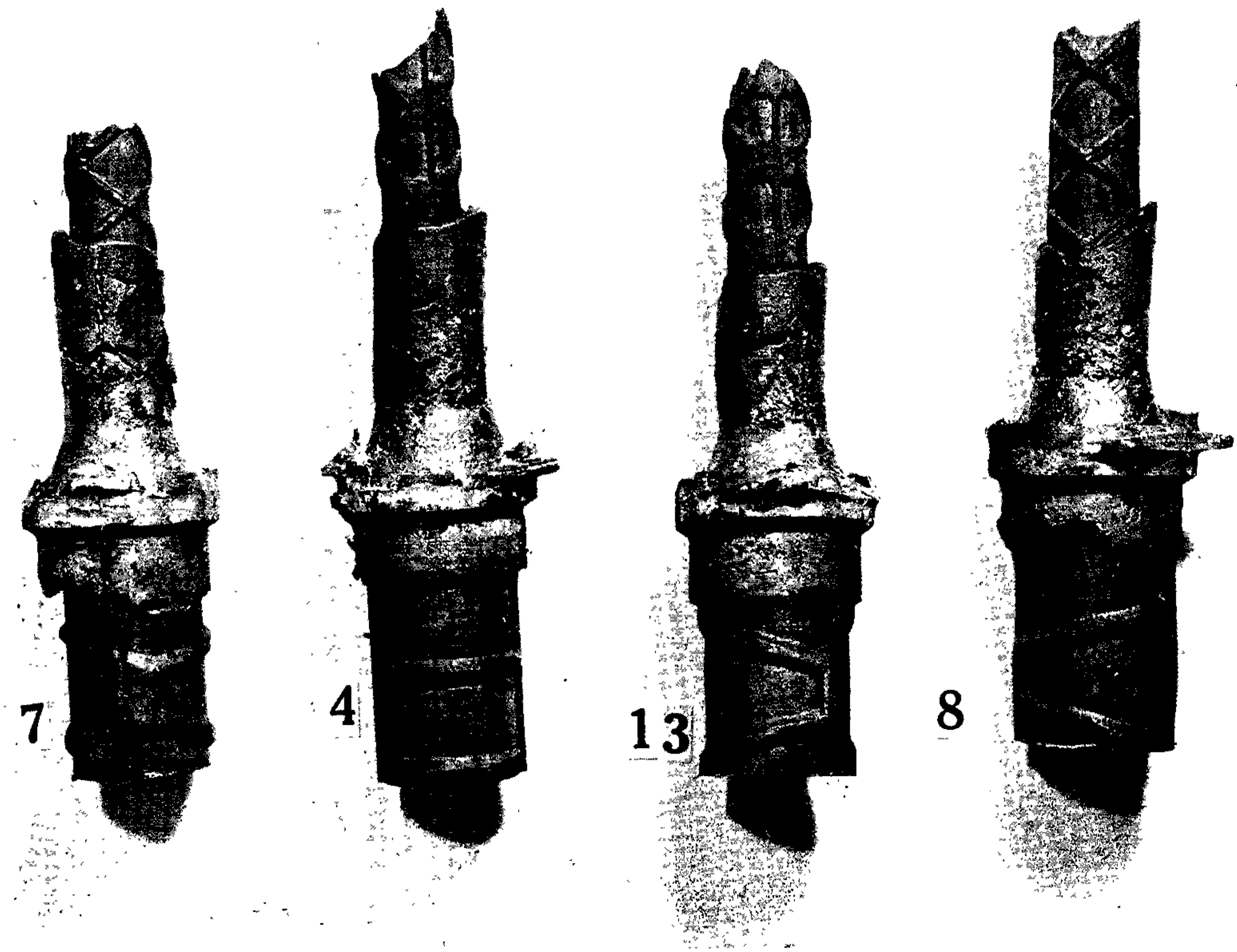
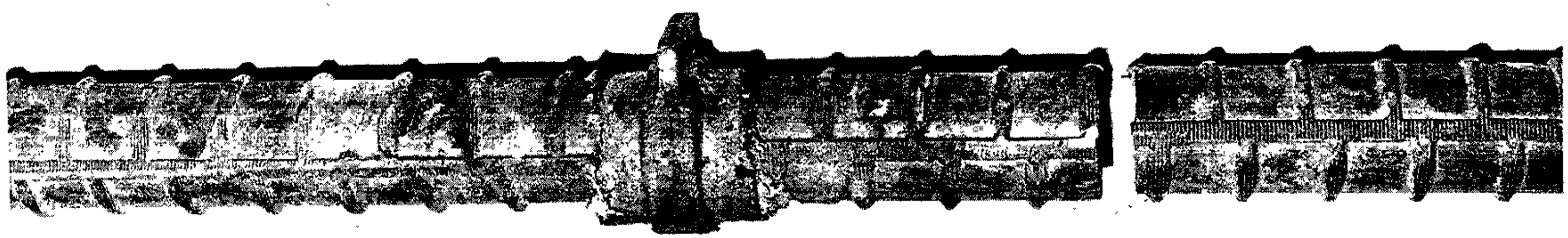


All thermit welded reinforcing bars of number 18 size bars to number 11 bars broke in the number 11 bars, approximately 6 inches from center of thermit weld.



Preheated #18 Reinforcing Bar
The Pacific States bar previously welded and broken and rewelded on opposite ends which were saw cut and preheated to 600° F. on each side of thermit weld for 6 to 8 inches.